International Journal of Mechanical and Production
Engineering Research and Development (IJMPERD)
ISSN (P): 2249-6890; ISSN (E): 2249-8001
Vol. 8, Issue 3, Jun 2018, 767-784

DESIGN AND ANALYSIS OF A HEAVY-DUTY DIESEL ENGINE PISTON

R. VIJAYAN[1], T. ARUN CHRISTOPHER[2], V. LOKESH KUMAR[3]
K. P. JAYANT KARTHICK[4] & N. PRAVEEN[5]

[1]*Assistant Professor, Department of Mechanical Engineering, Veltech, Avadi, Tamil Nadu, India*
[2,3,4,5]*Student, Department of Mechanical Engineering, Veltech, Avadi, Chennai, Tamil Nadu, India*

ABSTRACT

The main objective of this project is to study the characteristics of different alloys such as Steel, Aluminum and Cast Iron and to the design and analyze the stress distribution of the piston with a suitable material above the actual engine condition for a heavy duty diesel engine. In this paper, thermal analysis and mechanical analysis is done. The parameters used for the analysis are operating gas pressure, temperature and material properties of the piston. In I.C. Engine, a piston is most complex and important part therefore for the smooth running of the vehicle; piston should be in proper working condition. Piston fails mainly due to mechanical stresses and thermal stresses. Analysis of the piston is done with boundary conditions, which includes pressure on the piston head during working condition and uneven temperature distribution from piston head to skirt. The analysis predicts that due to temperature whether the top surface of the piston may be damaged or broken during the operating conditions and also to provide sufficient cooling conditions. The theoretical design calculations are made and the CAD model is created using CREO software. CAD model is then imported into the ABAQUS software for the analysis of stress distribution.

***KEYWORDS**: Design and Analyze, Analysis of Piston & Stress Distribution*

Received: Mar 13, 2018; **Accepted:** Apr 03, 2018; **Published:** Jun 01, 2018; **Paper Id.:** IJMPERDJUN201881

Original Article

INTRODUCTION

Diesel Engine

When all is said in done, a diesel motor can be characterized as a substantial obligation or a light-obligation motor, principally by its application to vehicles. On the off chance that it is utilized as a part of a substantial obligation vehicle, the diesel motor is guaranteed as an overwhelming obligation diesel motor, while in the event that it is utilized as a part of a light-obligation vehicle, it is known as a light-obligation diesel motor. Overwhelming obligation diesel motors are utilized far and wide to pull business vehicles because of their novel blend of mileage, solidness, dependability and reasonableness. A vehicle is characterized as overwhelming obligation if its gross vehicle weight rating (GVWR) is more noteworthy than 8500 pounds (3856 kg). The GVWR is the most extreme passable aggregate weight vehicle.[1]

Light-duty Diesel Engine

Light heavy-duty diesel engines ,as a rule, are non-sleeved and not intended for modifying. Their evaluated pull, for the most part, goes from 70 to 170 pounds (52.2 to 126.8 kW). Regular applications would incorporate individual transportation, light-stack business vehicles, and so on. The GVWR of these vehicles is ordinarily under 19 500 pounds (14 541 kg). [1]

Medium-Duty Diesel Engine

Medium heavy-duty diesel engines might be sleeved or non-sleeved and might be intended to reconstructing. Appraised horsepower ,for the most part, runs from 170 to 250 pounds (126.8 to 186.4 kW). Normal applications would incorporate business pick up, transports. Engines in this gathering are ordinarily utilized as a part of vehicles whose GVWR differs from 19 500 to 33 000 pounds (14 541 to 24 608 kg). [1]

Heavy-duty Diesel Engine

Heavy-duty diesel engines are sleeved and intended for various revamps. Their evaluated horsepower ,for the most part, surpasses 250 pounds (186.4 kW). Vehicles in this gathering are regularly tractors, trucks, and transports utilized as a part of whole deal applications. These vehicles typically surpass 33 000 pounds (24 608 kg) GVWR. [1]

A SURVEY OF CURRENT HEAVY-DUTY DIESEL ENGINES

Different propelled innovations have been utilized as a part of current heavy-duty diesel engines by real diesel motor makers to meet progressively stringent emanations conditions for predominant efficiency, execution, amiability, and unwavering quality. It is vital to choose the correct innovation and framework engineering for a specific application, execute the outline of equipment and control programming and upgrade the execution, mileage, and outflows through alignment controls utilizing the best accessible instruments.

Current heavy-duty diesel engines are turbocharged and utilize aerial charge air cooling to build charge air thickness and decrease NOx emissions. They include propelled fuel in fusion hardware (FIE) with high infusion weight from 1600 to 2400 bar, and full-specialist electronic control. These engines regularly have cooled fumes, gas distribution (EGR) innovation to additionally control NOx emissions. [1]

Piston

A piston is a component of reciprocating IC-engines. It is the moving component that is contained in a chamber and is made gas-tight by piston rings. In a motor, its motivation is to transfer constrain from expanding gas in the barrel to the crankshaft via a piston bar and/or associating pole. As an important part in a motor, piston perseveres through the cyclic gas weight and the inertial powers at work, and this working condition may cause the fatigue damage of the piston, for example, piston side wear, piston head/crown cracks and so on. The investigations indicate that the greatest pressure appears on the upper end of the piston and stress concentration is one of the main reason for fatigue failure. Then again piston overheating-seizure can just happen when something consumers or scrapes away the oil film that exists between the piston and the chamber wall. Understanding this, it's not hard to perceive any reason why oils with exceptionally high film qualities are extremely desirable. Great quality oils can give a film that stands up to the most extreme heat and the weight loads of a cutting-edge high yield motor. Thermal analysis is a branch of materials science where the properties of materials are considered as they change with temperature. FEM techniques are usually utilized for Thermal Analysis. Because of the complicated workplace for the piston; on one hand, the FEA for the piston became more difficult, then again, however, there have many techniques which are advanced to apply optimal outline, the optimal parameters are difficult to decide. In this examination, the piston is utilized as a part of low silt and rated speed gas motor. Keeping in mind the end goal to enhance the motor dynamic and economic, it is necessary for the piston to actualize optimization. The mathematical model of optimization is established right off the bat, and the FEA is carried out by utilizing the ANSYS

software. Based on the analysis of optimal outcome, the pressure concentrates on the upper end of the piston has progressed toward becoming evaluate, which gives a superior reference to upgrade of a piston. [3]

Cylinder Head Design

Most present heavy-duty diesel engines utilize the four-valve head. The intake and exhaust valve sizes are streamlined for maximum stream area while maintaining the injector location at the focal point of the cylinder to enhance fuel distribution and air/fuel blending. In general,the in-cylinder swirl is generated utilizing a standard swirl port outline for one intake valve location, and a tangential swirl port for the other. The valve seats are parent metal and acceptance hardened for wear resistance. In general, for frosty starting, each cylinder contains a sparkle plug, located between an intake and exhaust valve, and a projecting into the piston bowl. The opposite end of the sparkler plug juts to the outboard side of the motor, where it is associated with a wiring harness. The shine fittings can be serviced from outside the motor without evacuating the valve covers. [1]

The Piston

A piston is the important part in an engine which works and produces the outcome. Piston shapes a guide and bearing for the small end of connecting rod. It transmits the power of the blast in the cylinder, to the crankshaft through the connecting rod. Piston transmits the main impetus of combustion to the crankshaft and makes the crankshaft to rotate. They also act as a moveable gas-tight connect that keeps the combustion in the cylinder. It has to dispose of the heat from combustion. [2]

Material for Piston

Cast Iron, Aluminum Alloy and Cast Steel, etc. are the common materials used for the piston of an Internal Combustion Engine. Cast Iron pistons are not suitable for high-speed engines due to its more weight.

The Aluminum Alloy Piston is lighter in weight and enables much lower running temperatures because of its higher thermal conductivity. The coefficient of expansion of this sort of piston is about 20% not as much as that of unadulterated aluminum piston yet higher than that of cast iron piston. It has great machinability, light in weight and has great thermal conductivity. [2]

The Connecting Rod

The connecting rod interfaces the piston to the crankshaft. The upper end has a gap in it for the piston wrist pin and the lower end (enormous end) attaches to the crankshaft. It is under enormous worry from the reciprocating load of the piston. With each rotation, it is extended and compacted and the load increases to the third power with increasing engine speed. [2]

Connecting rods are mechanical components that change over the piston alternative motion in the crankshaft rotational motion. They are subjected to a mind-boggling state of stresses which incorporates compression stresses associated to the weight applied by the combustion gases, and tractable stresses related to the inertia of the components in motion, either alternative or rotational. Failures in con-rods have been accounted for in the literature, being associated with fatigue, overload twisting, bearing failure, despicably adjusted jolts, spalling, and assembly deficiencies. [5]

Materials for Connecting Rod

Steel is normally utilized for development of automobile connecting rods because of its strength, durability, and lower cost. Be that as it may, they have a high mass density and make the crankshaft heavy. This constrains the paces of the engine. Hence, light alloy metals, for example, aluminum and titanium are right now being utilized as a part of rapid engine connecting rods. Titanium has preferred mechanical properties over aluminum. However, is expensive. This higher density and cost have made aluminum connecting rods more popular and attractive. In any case, they experience the ill effects of relatively low strength and fatigue life. [2]

Crank Shaft

The crankshaft changes over the all over (reciprocating) motion of the pistons into a turning (rotary) motion. It gives the swinging motion to the wheels. The crankshaft is associated with the pistons by the connecting-rods. The crankshaft is made usually either with alloy steel or cast iron. [2]

Turbo Charger

The maximum power that a given diesel engine can convey is constrained by the amount of fuel that can be singed efficiently inside the engine cylinder. It is known from the hypothesis that the engine power, torque, and mean compelling weight are proportional to the gulf air density. On the off chance that the accepted air is compacted to a higher density than the ambient, preceding section into the engine cylinder, the maximum power which the engine can convey will be increased. A turbocharger, consisting of a compressor and a turbine on a solitary shaft, is broadly utilized as a part of heavy-duty diesel engines to support the channel air density. Vitality from the engine exhaust is utilized to drive the turbocharger turbine, which drives the turbocharger compressor which increases the delta air density preceding entering the engine cylinders. [1]

Aluminum Alloy -Al6061

Al6061 alloys contain the major solutes, for example, Mg and Si. Because of its exceedingly attractive properties, for example, high strength to weight ratio, great extrudability, weldability, great forgeability, and incredible consumption resistance, Al6061 is of great importance in many industrial applications. Industrial procedures, for example, fashioning and expulsion for this alloy are carried out in the high temperature range. [7] In the investigation of applied load of 1wt. %CNT fortified Al6061 composite produced by ball processing and spark plasma sintering (SPS) and compared to Al6061 monolithic alloy. Their finding revealed that, the wear rate increased linearly with the applied load. At bring downloads of5– 15 N, the composite displayed better wear resistance. At higher loads of 20– 30 N, the wear resistance of monolithic alloy was superior to the composite. [8] In Al 6061The greatest wear resistance was seen in the composite containing 60% Sic, which had a wear rate more than five times lower than the 20% Sic, composite when tried against SIC coarseness and more than thirty times bring down when tried against on the steel. [9]

This work investigated the impact of silicon carbide and graphite on the microstructure and mechanical behavior of Al6061-SiC and Al6061-Graphite composites. The investigation reveals the adequacy of integration of SiC and Graphite in the Al6061 alloy for concentrate mechanical properties. The composites were fabricated utilizing fluid metallurgy course. The Al6061-SiC and Al6061-Graphite composites were fabricated separately by introducing 9 wt. % of SiC and graphite particulates. [10] The precipitation hardening ,impact at 100, 150 and 200°C on the mechanical properties was

also investigated. Optical micrographs and Brinell hardness number have been discussed. Transmission electron microscope demonstrates precipitation of better between metallic in both Al6061 alloy and its composites. Increase in the percentage of both B4C and SiC support from 2-6% wt. and artificially aged at 100°C shows enhancement in hardness by 150-175% because of the precipitation of intermetallic phases of alloying components. Al6061-B4C composites demonstrate change in hardness as compared to Al6061-SiC composites. [11] This work investigated the impact of Al2O3 and graphite on the microstructure and mechanical behavior of Al6061-Al2O3 and Al6061-Graphite composites. The investigation reveals the viability of incorporation of Al2O3 and Graphite in the Al6061 alloy for concentrate mechanical properties. The composites were fabricated utilizing fluid metallurgy course. The Al6061-Al2O3 and Al6061-Graphite composites were fabricated separately by introducing 9 wt. % of Al2O3 and graphite particulates by two- stage dissolve mixing process.[12] Al6061-CNTs composite were produced utilizing horizontal attritor processing and SPS procedure at various sintering temperature. Al6061-CNT powder densified in ~100oC bring down temperature when compared with unreinforced Al6061. The CNTs acted as decreasing agent in the powder surface oxide film, which enhanced metal/metal bonding. The elasticity of the nanocrystalline aluminum fortified with CNT increased with increasing sintering temperature. CNT strengthening came about because of its impact on the grain estimate stability and Al4C3 formation at higher sintering temperature. [13]

1.0 wt.% graphene strengthened aluminum 6061 (Al6061) composite was blended to investigate the impacts of graphene dispersion by ball processing procedure. The Al6061 powder and graphene were ball processed at various processing times. The composites were then blended by hot compaction in the semi-strong administration of the Al6061. A three -point twisting test was performed to characterize the mechanical properties of the composite. The ball processed powder and the fracture surfaces of the composites were analyzed utilizing the scanning electron microscopy. A maximum enhancement of 47% in flexural strength was watched when compared with the reference Al6061 prepared at the same condition. [14]

STEEL ALLOY-EN24T

A right understanding of the state of as far as possible is of crucial importance in a discussion of the fatigue strength. Many cracks appear under cyclic stress if the stress is higher than a critical level. Most cracks keep on growing at a stress somewhat above as far as possible however some stop. Careful observation always reveals the existence of non-propagating cracks at a stress equal to as far as possible. In the early days of the history of fatigue research as far as possible was regarded as the critical condition for crack initiation, yet nowadays the fatigue furthest reaches of steels are perceived as the restricting condition for the non-propagation of cracks emanating from a matrix or imperfections. [15] The determination of the machinability of materials is finished by the measure of surface finish. Surface unpleasantness is an important measure of product quality since it greatly impacts the performance of mechanical parts as well as production cost. The Optimization of machining parameters increases the utility for machining economics and the product quality increases to a great degree as well. EN24 is an excellent, high pliable, alloy steel and joins high elasticity, stain resistance, great pliability and resistance to wear. EN24 is most suitable for the manufacture of parts, for example, heavy-duty axles and shafts, gears, jolts and studs. EN24 is capable of retaining great impact values at low temperatures. [16] Ni– Cr– Mo steels, for example, En24 steel is generally utilized as a part of machine part individuals, gears and shafts. En24 steel is generally utilized as a part of the hardened and tempered condition to achieve an ideal combination of hardness and malleability. [17] studies also relate the impact of oxide on setting and crevice consumption, resistance on both stainless

steels and broadly utilized low alloy steel EN24 in the marine environment, Reasons for failure of high strength 13% Cr steel in a gathering steam environment revealed the erosion fatigue sort of failure. [18]

EN24 displays higher hardness compared to that of EN8 and it is attributed to high amount of carbon and Cr introduce in EN24 compared to EN8. It is also watched that the steels with water extinguishing are brought about higher hardness compared to different treatments. This is because of the quality of higher cooling rates associated with water extinguishing compared to other heat treated steels. Higher cooling rates eventually leads to the formation of martensite structure which enhanced the hardness of these steels. EN 24 grade steel shows better consumption, resistance compared than that of EN8. In both the cases, erosion resistance of steels is low without heat treatment. Bunches of carbides are observed to be maximized in EN 8 grade steels and these carbide turning into the wellspring of galvanic coupling to show poor erosion resistance. [18]

En24 as-got, hardened– tempered and fluid nitride condition, when worried with hardened– tempered bearing steel. Tests were led at various normal loads and at constant slip amplitude under un-lubricated conditions. Coefficient of friction under worrying conditions and wear resistance was measured. Surface chemistry impacts the fussing wear behavior more than the hardness of the material. The monophase epsilon iron nitride structure of compound layer framed in the fluid nitrating process offers enhanced worrying wear resistance against bearing steels. The worrying wear resistance also relies on the normal load and the nature of contact, stick-slip or gross slip. [19]

To have increased device life and wear resistance, multicoated carbide embeds with a hard metal substrate have been as of late created, couple of investigations have been made on the wear mechanisms while machining En24 (817 M 40) steel so En 24 is prescribed for better strength and durability. [20]

Ball Indentation (BI) Technique has been utilized to evaluate the variation in mechanical properties because of heat treatment on as-got En steels. Augmentations in treating temperature have softened the samples and along these lines decreased the strength however increased strain hardening example. The completely martensitic structure has framed in solutions and oil extinguished sample, which enhanced the strength. The obtained aftereffects of as-got En steel are validated by conventional test outcomes. Optical microscopy and hardness values of heat treated En steels corroborated the BI obtained comes about. All confirmations demonstrated that BI system is valuable and a powerful small example strategy to evaluate small changes in mechanical properties with no earlier analysis. [21]

The end goal is to investigate the impacts of non-metallic consideration of the fatigue strength, of high-strength steels, for example, En 24 that contained artificially added spherical and angular alumina particles of various controlled sizes. Although the fatigue tests were carried out under the same nominal stresses in rotating-twisting and strain compression tests the fatigue lives of examples demonstrated a large scatter. They announced in some detail typical complicated aspects of the impacts of non-metallic incorporations on the fatigue strength. [22]

EXPERIMENTAL PROCEDURE

Piston Design

THICKNESS OF PISTON HEAD

$T_H = \sqrt{(3PD^2/16\sigma)}$

HEAT FLOW

RADIAL THICKNESS OF RING

$T_1 = D\sqrt{(3Pw/t)}$

AXIAL THICKNESS OF RING

$T_2 = 0.7T_1$ to T_1

No. of Rings

$i = D/10$

WIDTH OF TOP LAND

$B_1 = T_H$ to $1.2T_H$

WIDTH OF OTHER RING LANDS

$B_2 = T_H$ to $1.2T_H$

MAX. THICKNESS OF BARREL

$T_3 = 0.03D + B + 4.5$

B = Radial depth of ring groove

$B = T_1\text{-}0.4$

WALL THICKNESS TOWARDS OPEN END

$T_4 = 0.25T_3$ to $0.35T_2$

The Fea of the Piston

In an engine, transfer of heat takes place because of distinction in temperature and from higher temperature to bring down the temperature. Along these lines, there is heat transfer to the gases amid intake stroke and the initial segment of the compression stroke, yet the amid combustion and expansion forms the heat transfer take place from the gases to the walls. So the piston crown/head, piston ring and the piston skirt ought to have enough solidness which can persevere through the weight and the friction between contacting surfaces. In addition, as an important part in an engine, the working state of piston is specifically related to the reliability and durability of the engine. So it is important for the piston skirt and the piston ring carrying out structural and optimal analysis, which can give reference to the outline of the piston. So the mean compelling weight of the piston crown, piston top ring and the piston skirt ought to be restricted at low sit out of gear and at rated speed. [3]

The formula can be expressed as,

$$IHP = \frac{P_m * L * A * N/2}{60 * 10^2}$$

Where, P_m Mean Effective Pressure (bar);

L- Stroke length (mm);

A –Area (mm2);

N-speed (rpm);

IHP- indicated horsepower (watt).

NUMERICAL ANALYSIS OF STEADY-STATE TEMPERATURE FIELD

Boundary Condition for Thermal Numerical Analysis

The initial and boundary conditions should be resolved before the conduction of the limited component analysis. The environment is diverse with regards to various parts of the piston. As said previously, the environment for the piston top is combustion chamber, meanwhile the environment for the piston skirt is the crankcase, the environment for the cooling cavity is cooking oil, and the environment for the piston ring is combustion chamber. [6]

Radius Equivalent Heat Transfer Coefficient of Piston Top

Adjusted Seal-Taylor empirical formula was chosen to calculate the heat transfer coefficient on the piston top. [6]

Heat Transfer Coefficient of the Piston Cooling Cavity

The piston cooling cavity is in charge of approximately 86 ~ 95% of the total heat dissipation, speaking to the best way to cool the engine. So the cooling cavity is broadly utilized as a part of the fast and large power diesel engine. Because of the reciprocating motion of the piston, the cooling oil in the cooling cavity has a solid impact on the piston, which brings about a high surface heat transfer coefficient. The heat transfer coefficient which is calculated by the French revised formula is greater than that calculated by the Bush formula, because the constant coefficient of the French adjustment formula is greater. The heat transfer coefficient of the inside cooling oil cavity is smaller than that of the annular cooling oil cavity, because of the smaller equivalent diameter of the annular cooling oil chamber. The highest point of the cooling cavity is subjected to repeated impact of cooling oil, so the heat transfer coefficient at this area ought to be calculated by the French amendment formula. For the central cooling cavity, the impact isn't self-evident, so the Bush formula ought to be utilized. So, as to get more accurate outcomes, it is joined with the invert calculation technique, the cooling cavity keeps on being sub-partitioned into four locales. [6]

Heat Transfer Coefficient of Piston Top Land (The First Ring Bank)

The piston top land is the nearest to the gas, so the temperature of the best land is high, up to 400 °C. [6]

Heat Transfer Coefficient of the Piston Ring and Skirt

The heat transfer, display in favor of the piston can be equivalent to a multi-layer flat plate shows heat transfer demonstrate. [6]

Heat Transfer Coefficient of the Piston Skirt Inner Surface

To obtain the heat transfer coefficient of the inward surface of the piston skirt, the basic formula of heat conduction and convection with the heat balance equation. The extent of the total heat dissipation capacity of the piston skirt is not high and the temperature of the inward cavity of the piston skirt is low. [6]

Determination of Final Heat Transfer Coefficient

The initial heat transfer coefficient is resolved according to empirical or semi-empirical formulas. So it's necessary to adjust the heat transfer coefficient and the average temperature for each area. Right off the bat, take the initial

and boundary conditions were introduced into FEM, at that point the simulation comes about were compared against the measured temperature values, the measured temperature values of reference focuses on the piston surface is given. [6]

THE TRANSIENT-STATE TEMPERATURE FIELD OF THE PISTON

Boundary Condition of Transient Analysis

In each cycle of diesel engine, instantaneous temperature of gas in the cylinder changes at any time, causing the temperature fluctuations on the piston. When examining the transient-state temperature field fluctuations of the piston, thermal boundary conditions at the piston best will change with the fluctuation of the gas temperature. [6]

Thermal Stress Analysis of Piston

Because the material has the characteristics of expansion caused by heat and contraction caused by frost, under the action of temperature it will be disfigured. At the point when the thermal deformation is constrained, thermal stress appears. Here the forced constraints can be caused by the environment or the distinction of thermal expansion coefficient of the various materials. The thermal stress caused by the uneven temperature field, i.e. the temperature gradient, is generally normal.

In general, the diesel engine piston thermal load is more genuine than that of the gasoline engine, because the heating conditions in the diesel engine are more regrettable. From one viewpoint, diesel fuel presents higher working medium density, more grounded disturbance stream in the compression stroke, higher weight rise rate, causing the larger temperature gradient and the promotion of convective heat transfer, then again, diesel engine piston is inclined to carbon affidavit, which could significantly block the heat exchange of the piston. In addition, the combustion of the fuel without uniform atomization usually makes the temperature distribution more uneven. In this way, the thermal stress analysis on the basis of the temperature field is particularly important. [6]

WORKING PROCEDURE

Study of EN24T Alloy: SAE: AISI 4340 EN24 is usually supplied in the final heat treated condition (quenched and tempered, which is called "T" condition) up to a limiting ruling section of 250mm, which is superior to grades 605M36, 708M40 or 709M40. EN24 is a very popular grade of through-hardening alloy steel, which is readily machinable in the "T" condition. EN24T is most suitable for the manufacture of parts such as heavy-duty axles and shafts, gears, bolts, and studs. EN24T can be further surface-hardened, typically to 58-60 HRC by induction or nitride processes, producing components with enhanced wear resistance. In addition to the above, EN24T is capable of retaining good impact values at low temperatures, hence it is frequently specified for harsh offshore applications such as hydraulic bolt tensioners and ship -borne mechanical handling equipment.

It is therefore recommended that larger sizes are supplied in the annealed (softened) condition, and that quenching and tempering are carried out after initial stock removal. This should achieve better mechanical properties towards the core.

Table 1: Chemical Composition of EN24T Alloy

Element	Weight (%)
Chromium, Cr	1.00 – 1.40
Manganese, Mn	0.45 – 0.70
Carbon, C	0.36 - 0.44
Silicon, Si	0.10 - 0.35
Molybdenum, Mo	0.20 - 0.35
Sulphur, S	0.040 Max
Phosphorous, P	0.035 Max
Nickel	1.30 – 1.70
Iron, Fe	Balance

Study of AL6061 Alloy

6061 isa precipitation-hardened aluminumalloy,containing magnesium and silicon asits major alloying elements. Originally called "Alloy 61S", it was developed in 1935. It has good mechanical properties, exhibits good weldability, and is very commonly extruded. It is one of the most common alloys of aluminum for general-purpose use construction of aircraft structures, such as wings and fuselages, more commonly in homebuilt aircraft than commercial or military aircraft. Yacht construction, including small utility boats. Automotive parts, such as the chassis, Piston, bearings, etc.

Table 2: Composition of Al-6061 Alloy

Component	Amount (wt.%)
Aluminum, Al	Balance
Magnesium, Mg	0.8-1.2
Silicon, Si	0.4 – 0.8
Iron, Fe	Max. 0.7
Copper, Cu	0.15-0.40
Zinc, Zn	Max. 0.25
Titanium,	Max. 0.15
Manganese, Mn	Max. 0.15
Chromium, Cr	0.04-0.35
Others(Ni,V, Mo)	0.05

Table 3: Why Steel Alloy ?

Properties	EN24T	Al-6061
Density	7840 kg/cm^3	2700 kg/cm^3
Ultimate Tensile strength	850 – 1000 Mpa	290 – 310 Mpa
Yield Tensile strength	650 – 680 MPa	270 – 280 MPa
Elastic modulus	210 GPa	70 – 80 Gpa
Poisson's ratio	0.27 – 0.3	0.33
Hardness, Brinell	248 – 302	97
Thermal Conductivity	42 W/mK	173 W/mK

Table 4: Design of a Piston:

S.No.	DESCRIPTION	VALUE
Max. Pressure = 180bar; Heat flow = 12% of 9KW; Diameter = 114mm		
1.	Thickness of head	13.5mm
2.	Radial Thickness of Ring	3.6mm
3.	Axial Thickness of Ring	3.6mm
4.	No. of Rings	3
5.	Width of Top Land	13.5mm
6.	Width of other Ring Lands	3.6mm
7.	Max. Thickness of Barrel	11.12mm
8.	Radial Depth of Ring Groove	3.2mm
9.	Wall Thickness towards open end	3mm
10.	Length of Piston Pin	100mm
11.	Diameter of Piston Pin	51mm
12.	Distance of Piston Pin from Head	72mm
13.	Length of Piston	111.9mm

Piston Calculation

Given:

Pressure, P = 180bar

Diameter, D = 114mm

H = 12% of 9KW

Material: Steel Alloy

Max stress, σ = 240 MPa

Thickness of Piston Head

TH = √(3PD2/16σ)

TH = 13.5mm

Heat Flow, H = 10.8KW

Radial Thickness of Ring

Let Pw = 0.03N/mm2

t = 90N/mm2 (C.I)

T1 = D√(3Pw/t)

T1 = 3.6mm

Axial Thickness of Ring

T2 = 0.7T1 to T1

T2 = 3.6mm

No. of Rings, i = D/10T2 = 3

Width of Top Land

B1 = TH to 1.2TH

B1 = 13.5mm

Width of Other Ring Lands

B2 = TH to 1.2TH

B2 = 3.6mm

Max. Thickness of Barrel

T3 = 0.03D + B + 4.5

B = Radial depth of piston ring groove

B = T1-0.4 = 3.2mm

T3 = 11.12mm

Piston Wall Thickness towards Open End

T4 = 0.25T3 to 0.35T2

T4 = 3mm

Other Characteristics

Length of piston, L = 111.9mm

Piston Pin Diameter, d = 51mm

Referred from “Fundamentals of machine Design” by ‘T.J. Prabhu’

Width of Top Land

B1 = TH to 1.2TH

B1 = 13.5mm

Width of Other Ring Lands

B2 = TH to 1.2TH

B2 = 3.6mm

Max. Thickness of Barrel

T3 = 0.03D + B + 4.5

B = Radial depth of piston ring groove

B = T1-0.4 = 3.2mm

T3 = 11.12mm

Piston Wall Thickness towards Open End

T4 = 0.25T3 to 0.35T2

T4 = 3mm

Other Characteristics

Length of piston, L = 111.9mm

Piston Pin Diameter, d = 51mm

Referred from "Fundamentals of machine Design" by 'T. J. Prabhu

Table 5: Stress Analysis with Al6061

Input Parameters	
Properties	**Metric**
Density	2700 Kg/cm^3
Ultimate Tensile strength	310MPa
Yield Tensile strength	276 MPa
Elastic modulus	70-80 GPa
Poisson's ratio	0.33
Hardness, Brinell	95-97
Pressure	180 bar
Mass	1.505Kg

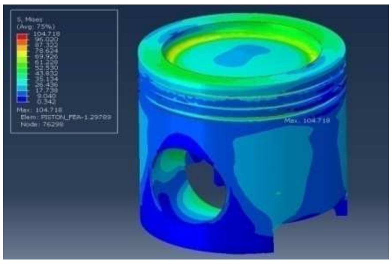

Figure 1

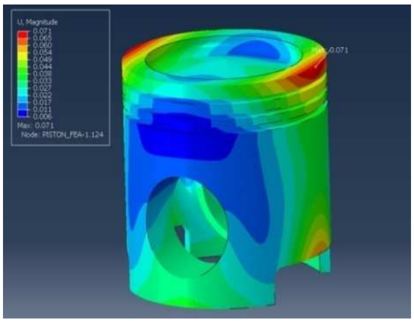

Figure 2

STRESS ANALYSIS WITH EN24T ALLOY (PISTON & PIN)

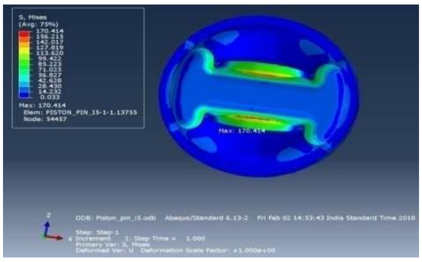

Figure 3

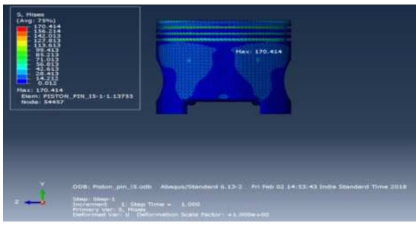

Figure 4

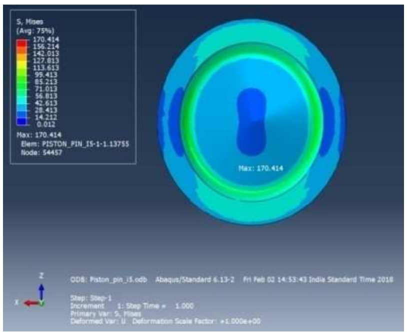

Figure 5

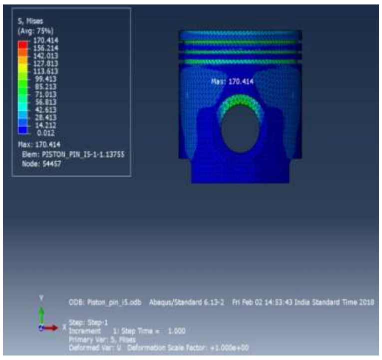

Figure 6

Table 6

Parameters	
Properties	**Metric**
Density	7840 Kg/cm^3
Ultimate Tensile strength	850 – 1000 MPa
Yield Tensile strength	650 – 680 MPa
Elastic modulus	210 GPa
Poisson's ratio	0.27
Hardness, Brinell	248 – 302
Pressure	180 bar
Mass	2.70 Kg

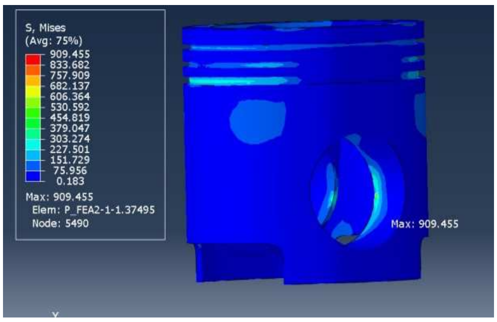

Figure 7

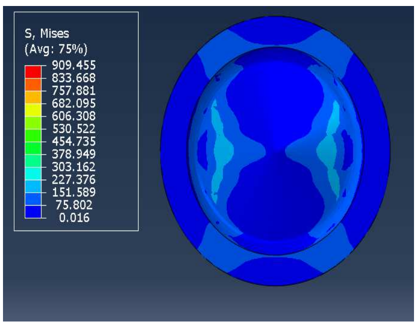

Figure 8

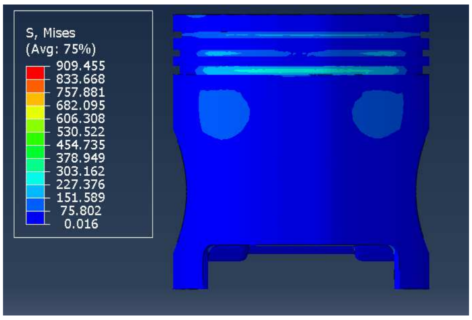

Figure 9

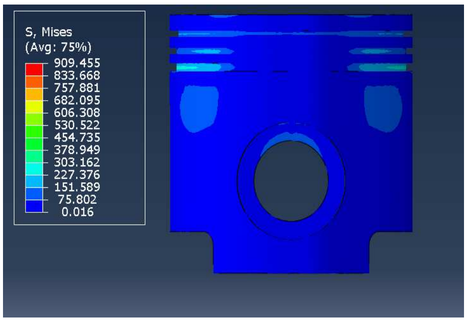

Figure 10

CONCLUSIONS

Based on the above iterations best design has been selected with a minimum weight of 2.70 kg and the maximum stress of 909.455 MPa, The boundary conditions are limited to the values Maximum pressure = 180 bars, Displacement U1=0, U2=0, U3=0.

REFERENCES

1. *Overview of heavy-duty diesel engines - Z. Liu, Navistar Inc., USA.*
2. *Analysis of Piston, Connecting rod and Crank shaft assembly, ChinthalapudiEngg College, India.*
3. *Thermal Analysis And Optimization Of I.C. Engine Piston Using finite Element Method - A. R. Bhagat, Y. M. Jibhakate, KITS College of Engineering Nagpur, India.*
4. *Fundamentls of machine Design - T.J. Prabhu*
5. *Failure analysis of a diesel generator connecting rod - C. Juarez, F. Rumiche, A. Rozas, J. Cuisano, P. Lean, Pontificia Universidad Catolica del Peru, Lima, Peru*
6. *Analysis of Thermal Temperature Fields and Thermal Stress under Steady Temperature field of Diesel Engine Piston Yaohui Lu, Xing Zhang, Penglin Xiang, Dawei Dong*
7. *Prediction of the flow stress of Al6061 at hot deformation conditions GanChunleia, XueYongdongb, Wang Mengjunc*
8. *Microstructural and tribological properties of nanostructured Al6061-CNT produced by mechanical milling and extrusion Mahdi Omidi,AlirezaKhodabandeh,Said Nategh, MehrdadKhakbiz*
9. *Wear behaviour of AA6061 aluminium alloy and its composites A.B. Gurcan, T.N. Baker*

10. *Synthesis and characterization of Al6061-SiC-graphite composites fabricated by liquid metallurgy by MadevaNagaral[a]VAuradi[a]K.I.Parashivamurthy[b]S.A.Kori[c]B.K.Shivananda[d]*
11. *Enhancement in Hardness and Influence of Artificial Aging on Stir Cast Al6061-B_4C and Al6061-SiC Composites M.C.GowriShankar[a]ManjunathShettar[b]S.S.Sharma[b]AchuthaKini[a]Jayashree[a]*
12. *Mechanical Behavior of Al6061-Al_2O_3 and Al6061-Graphite Composites Author links open overlay panelMadevaNagaral[a]B.K.Shivananda[b]V.Auradi[a]K.I.Parashivamurthy[c]S.A.Kori[d]*
13. *Microstructure and mechanical characterization of Al6061-CNT nanocomposites fabricated by spark plasma sintering A.A.NajimiH.R.Shahverdi*
14. *Mali, Arvind,Vijayalaximi. Pandit, and Devipriya. Majumder. "Biosorption of heavy metals by dead fungal biomass." IJCSEIERD 4.3 (2014): 11-20.*
15. *Effect of ball milling on graphene reinforced Al6061 composite fabricated by semi-solid sintering by MinaBastwros[a]Gap-YongKim[a]CanZhu[a]KunZhang[b]ShirenWang[b]XiaoduanTang[a]XinweiWang[a]*
16. *Quantitative evaluation of effects of shape and size of artificially introduced alumina particles on the fatigue strength of 1.5Ni-Cr-Mo (En24) steel by Y. Murakami, K. Kawakami and W.E. Duckwort*
17. *Optimization of Cutting Parameters in Dry Turning Operation of EN24 Steel Rahul Davis1,Jitendra Singh Madhukar2, Vikash Singh Rana3, Prince Singh4*
18. *Structural and Wear Characterization of Heat Treated En24 Steel Rajesh K. KHATIRKAR, Prashant YADAV and Sanjay G. SAPATE*
19. *An Experimental Study on Corrosion Behavior of En8 and En24 Grade Steels Aparnadevi.Ia,Sudhakar.Ib*, V.S.N. VenkataRamana*
20. *Fretting wear behavior of liquid nitrided structural steel, En24 and bearing steel, En31,R.RameshR.Gnanamoorthy*
21. *Some investigations of the wear mechanisms of widalon carbide inserts in machining EN24 (317 M 40) steel,B.P.SarmahM.K.Khare*
22. *Ball Indentation Technique: A currently developed tool to study the effect of various heat treatments on the mechanical properties of En24 steel,SabitaGhosh[a]SandipYadav[b]GoutamDas[a]*
23. *Quantitative evaluation of effects of shape and size of artificially introduced alumina particles on the fatigue strength of 1.5Ni瑕Cr瑕Mo (En24) steel Y.MurakamiK.KawakamiW.E.Duckworth*